PARTON DISTRIBUTIONS
AT LARGE x

STEFANO FORTE
UNIVERSITÀ DI MILANO & INFN

UNIVERSITÀ DEGLI STUDI DI MILANO
DIPARTIMENTO DI FISICA

INFN Istituto Nazionale di Fisica Nucleare

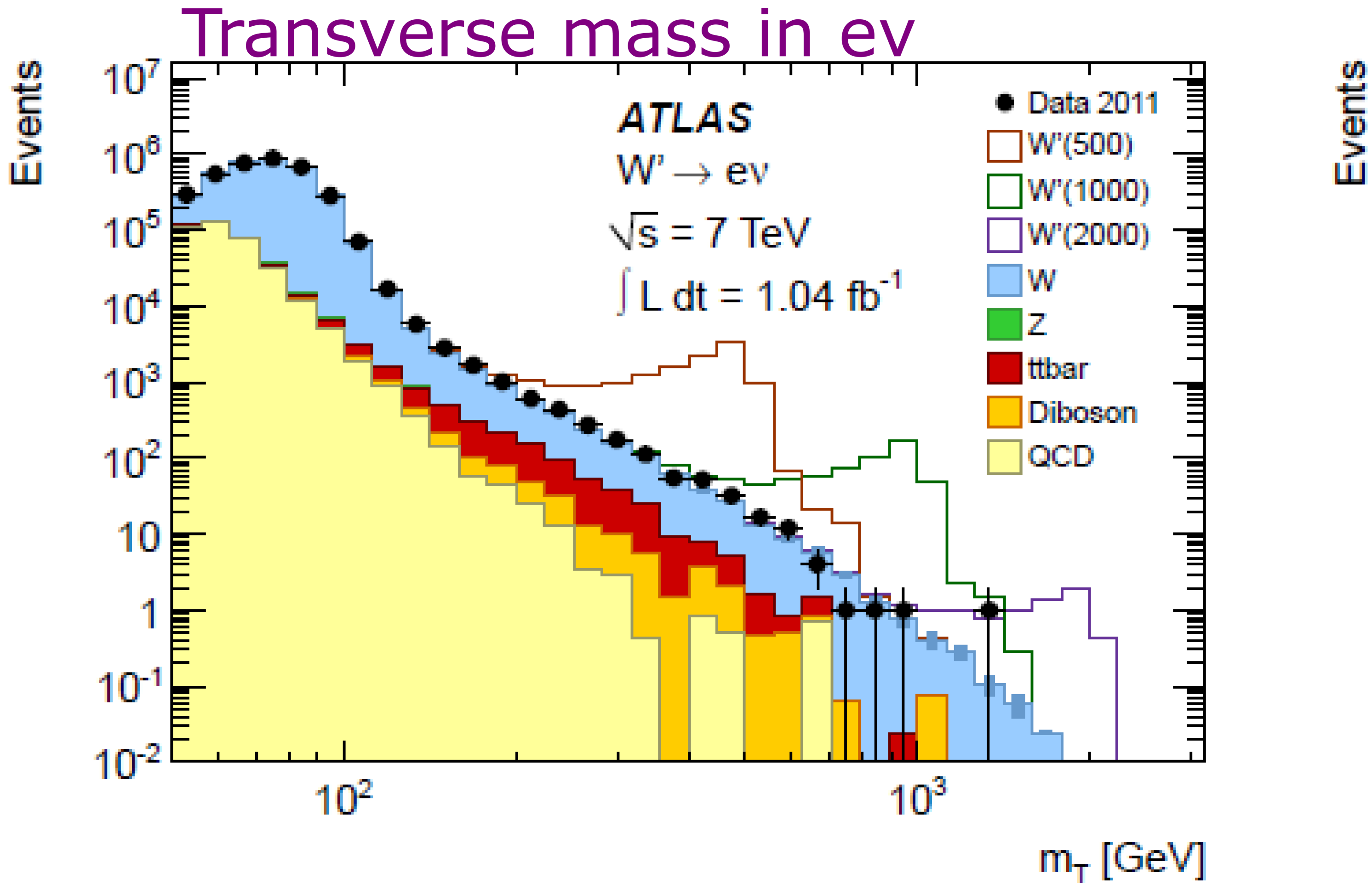
PDF4LHC

CERN, APRIL 17, 2013

THE MOTIVATION
SEARCHES FOR NEW PHYSICS

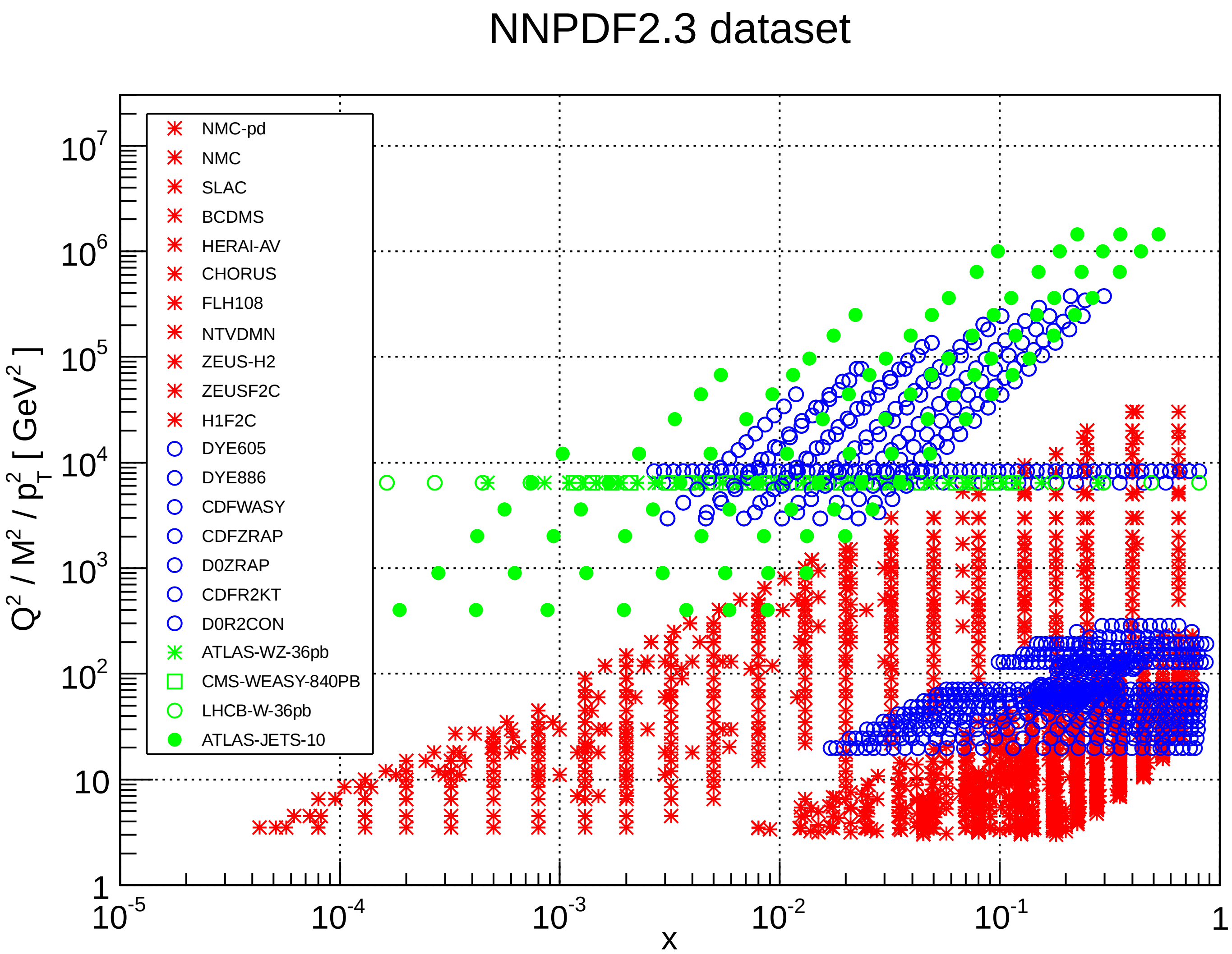
PDFs AT LARGE x DOMINATE SEARCHES FOR NEW PHYSICS

EXAMPLE': W' SEARCHES AT CMS



PDFs WITH $x \geq \tau = \frac{Q^2}{s}$ *contribute.*

CURRENT GLOBAL DATASETS

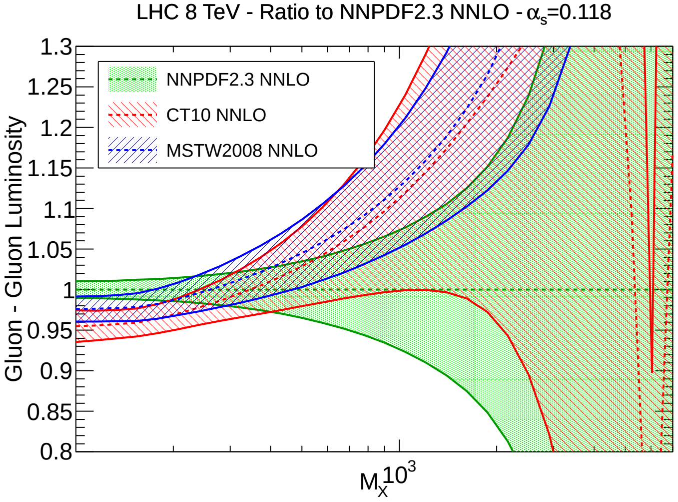


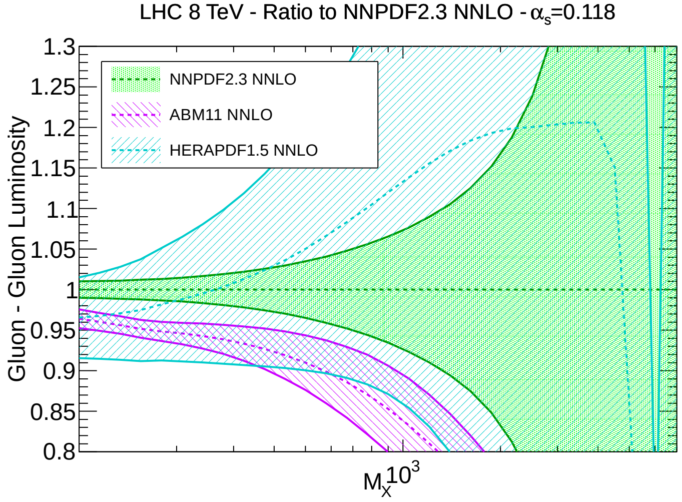
- DIS DATA HAVE $x < 0.6$
- TEVATRON DATA EXTEND TO SLIGHTLY HIGHER x, BUT LARGE UNCERTAINTIES
- LHC DATA MIGHT COVER THE HIGH x REGION

PARTON LUMINOSITIES AT LARGE X

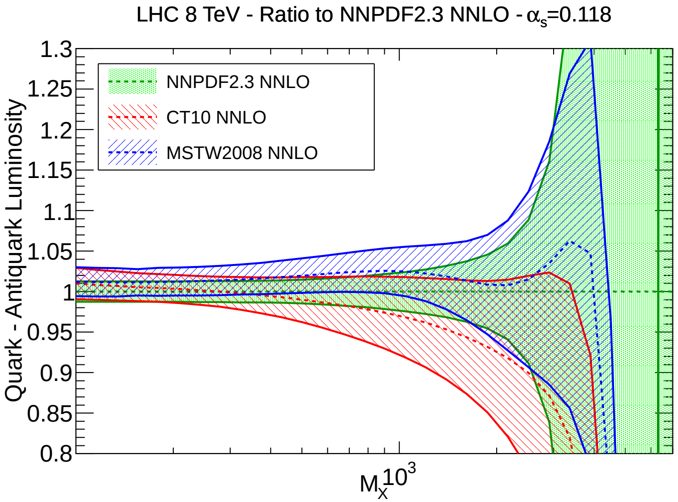
SHOWN AS RATIOS TO NNPDF2.3, VS MASS OF FINAL STATE (GeV, UP TO 7 GeV @ LHC8)

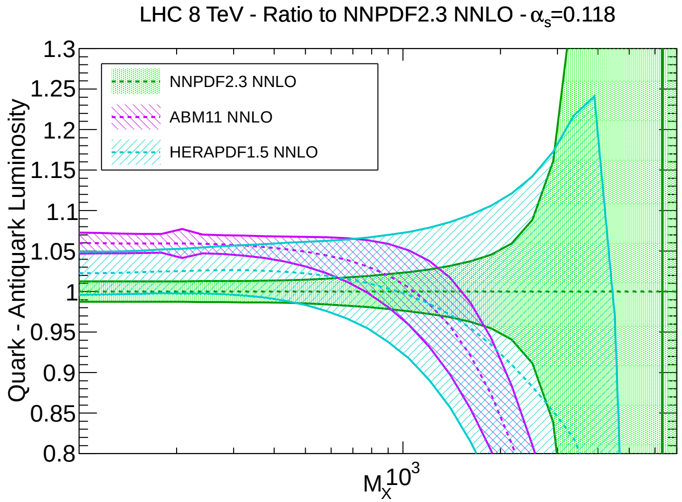
GLUON-GLUON LUMINOSITY





QUARK-QUARK LUMINOSITY





- UNCERTAINTIES BLOW UP AT LARGE M_X
- PERHAPS NOT ENOUGH IN qq CHANNEL

SUMMARY

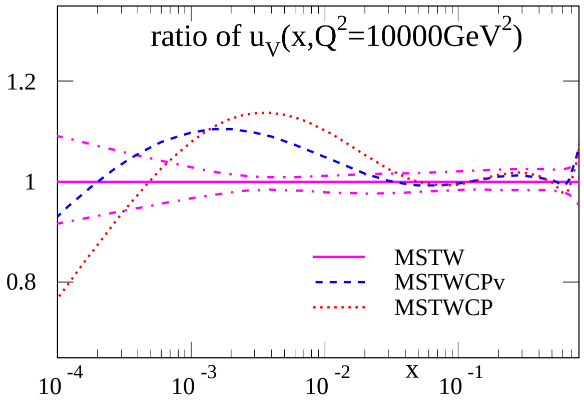
- PARAMETRIZATION BIAS
- NUCLEAR CORRECTIONS
- THRESHOLD RESUMMATION

PARAMETRIZATION DEPENDENCE

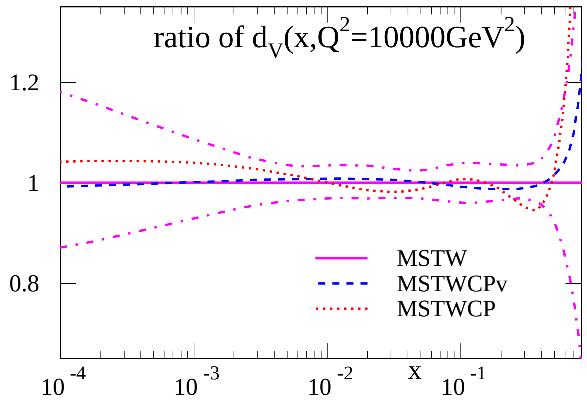
MSTW/MMSTWW: SEE ROBERT'S TALK AT SEPTEMBER '12 MEETING

- STANDARD FORM: $q_v = A_q x^{\alpha_q}(1-x)^{\beta_q^2}(1+\epsilon_q\sqrt{x}+\gamma_q x)$; $\beta_u = 3.36^{+0.06}_{-0.04}$; $\beta_d = \beta_u + 2.79^{+0.50}_{-0.44}$
- EXTENDED FORM: $q_v A_q x^{\alpha_q}(1-x)^{\beta_q^2}\left[1+\sum_{i=1}^{n} a_i T_i(y(x))\right]$; $y = 1-2\sqrt{x}$, $T_i(y)$ CHEBYSHEV POLYNOMIALS

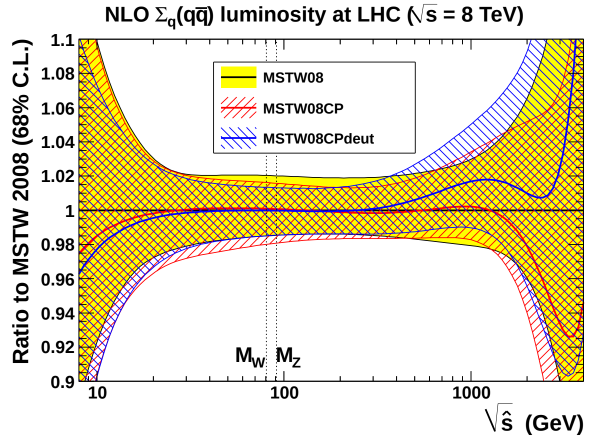
UP VALENCE



DOWN VALENCE



QQBAR LUMI



- VISIBLE CHANGES OUTSIDE DATA REGION
- VALENCE CHANGES MOSTLY AT SMALL x
- AT VERY LARGE x, NEW CENTRAL VALUE AT EDGE OF UNCERTAINTY BAND

PARAMETRIZATION DEPENDENCE

NNPDF

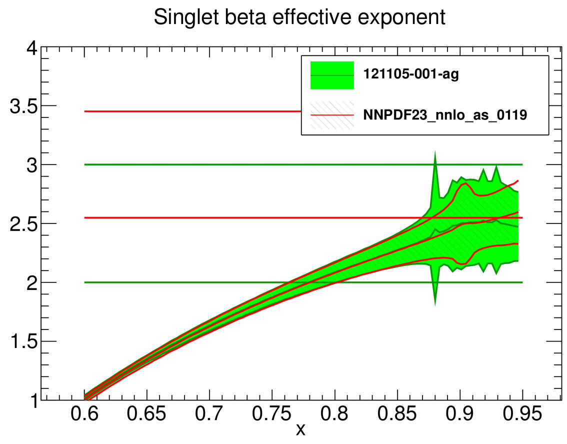
- PDFs parametrized by $f(x) = x^{\alpha}(1-x)^{\beta} NN(x)$;
- NN neural net with large no. of parms
- α, β (preprocessing) randomly varied in wide interval (only kick in in extrapolation region); range determined from stability of fit quality
- determine effective exponents $\alpha_{\text{eff}} = \frac{\ln f}{\ln x}$; $\quad \beta_{\text{eff}} = \frac{\ln f}{\ln(1-x)}$
- repeat fit with wider range of α, β & compute again effective exponents

PARAMETRIZATION DEPENDENCE

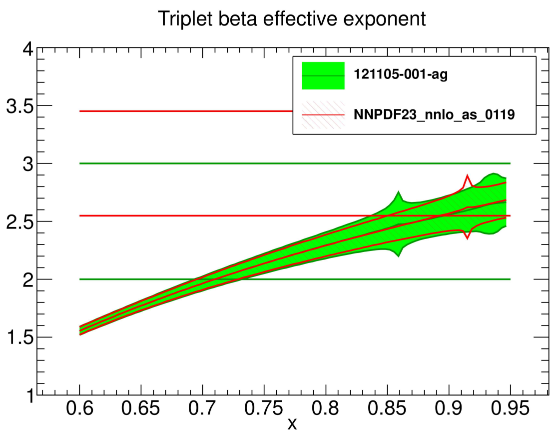
NNPDF

- PDFs PARAMETRIZED BY $f(x) = x^\alpha (1-x)^\beta NN(x)$;
- NN NEURAL NET WITH LARGE NO. OF PARMS
- α, β (PREPROCESSING) RANDOMLY VARIED IN WIDE INTERVAL (ONLY KICK IN IN EXTRAPOLATION REGION); RANGE DETERMINED FROM STABILITY OF FIT QUALITY
- DETERMINE EFFECTIVE EXPONENTS $\alpha_{\rm eff} = \frac{\ln f}{\ln x}$; $\beta_{\rm eff} = \frac{\ln f}{\ln(1-x)}$
- REPEAT FIT WITH WIDER RANGE OF α, β & COMPUTE AGAIN EFFECTIVE EXPONENTS

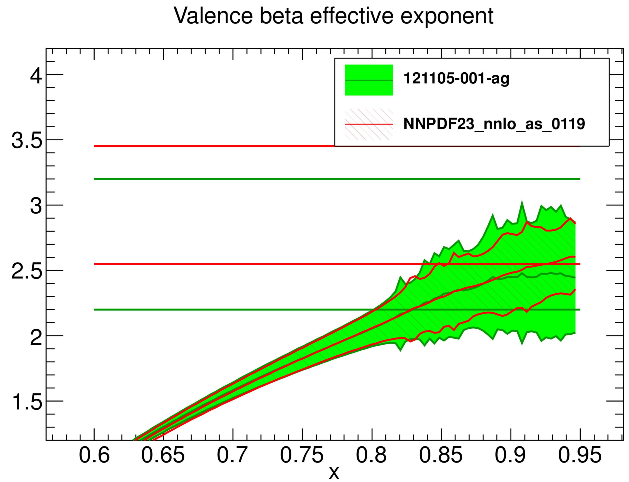
SINGLET



VALENCE



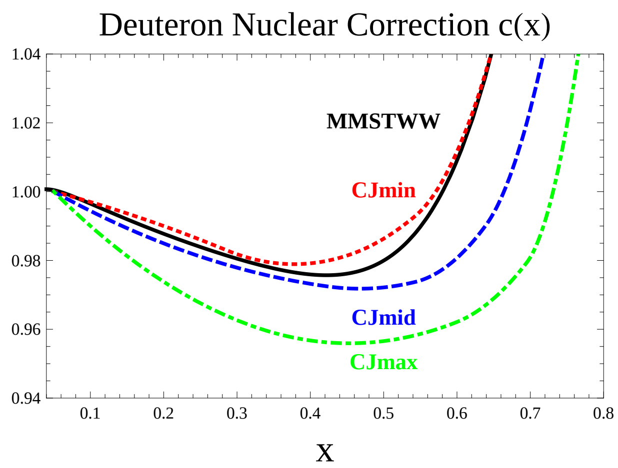
TRIPLET



- SOME WIDENING OF RANGE
- MUST ITERATE UNTIL CONVERGENCE FOR COMPLETELY UNBIASED RESULTS

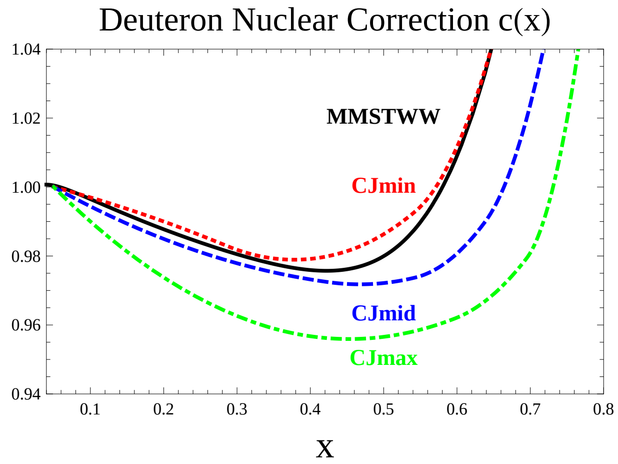
NUCLEAR CORRECTIONS (DEUTERIUM)

- DEUTERIUM DIS AND FIXED-TARGET DY DATA INCLUDED IN GLOBAL FITS
- MSTW/MMSTWW FITTED NUCLEAR CORRECTIONS TO F_2^d
- CJ (CTEQ/JLAB) COMPUTED NUCLEAR CORRECTIONS TO F_2^d USING MODELS
- NNPDF REPEATED FIT INCLUDING EITHER CT OR MMSTWW CORRNS

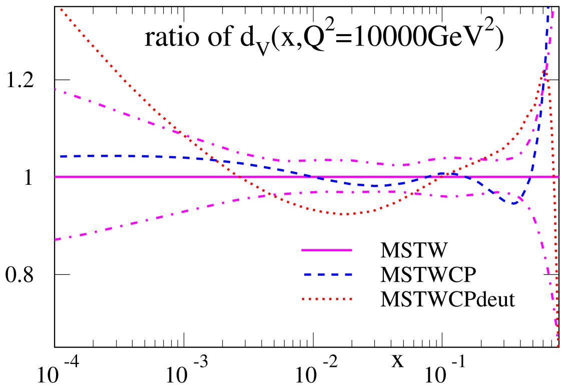


NUCLEAR CORRECTIONS (DEUTERIUM)

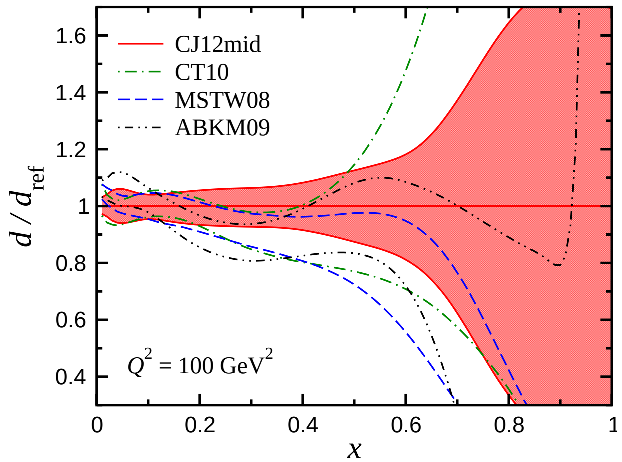
- DEUTERIUM DIS AND FIXED-TARGET DY DATA INCLUDED IN GLOBAL FITS
- MSTW/MMSTWW FITTED NUCLEAR CORRECTIONS TO F_2^d
- CJ (CTEQ/JLAB) COMPUTED NUCLEAR CORRECTIONS TO F_2^d USING MODELS
- NNPDF REPEATED FIT INCLUDING EITHER CT OR MMSTWW CORRNS



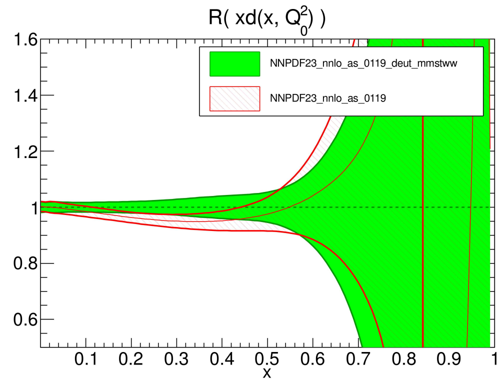
VALENCE D: MMSTWW (RAT. TO UNCORR.)



D: CJ (RAT. TO CORR.)



D: NNPDF (RAT. TO CORR.)



- IMPACT SIMILAR FOR ALL GROUPS: D QUARK MOSTLY AFFECTED, EFFECT PEAKS AT $x \sim 0.4$
- CJ SMALLER UNCERTAINTIES BECAUSE OF INCLUSION OF LOW W^2 DATA
- NNPDF WIDER UNCERTAINTIES BECAUSE OF NN PARAMETRIZATION
- IMPROVEMENT IN FIT QUALITY: MMSTWW, CJ MODERATE, NNPDF NONE

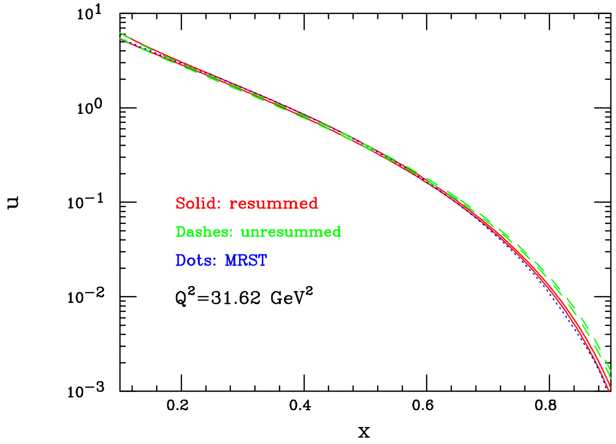
RESUMMATION

- PARTONIC CROSS SECTION RECEIVES DOUBLE LOG CORRECTIONS $\alpha_s \ln^2(1-z)$ TO ALL ORDERS IN $\alpha_s \Rightarrow$ THRESHOLD (SUDAKOV) RESUMMATION
- IN $\overline{\mathrm{MS}}$ SCHEME ONLY PARTONIC CROSS SECTION AFFECTED (NOT DGLAP EVOLUTION)

RESUMMATION

- PARTONIC CROSS SECTION RECEIVES DOUBLE LOG CORRECTIONS $\alpha_s \ln^2(1-z)$ TO ALL ORDERS IN $\alpha_s \Rightarrow$ THRESHOLD (SUDAKOV) RESUMMATION
- IN $\overline{\mathrm{MS}}$ SCHEME ONLY PARTONIC CROSS SECTION AFFECTED (NOT DGLAP EVOLUTION)
- RESUMMATION AFFECTS BOTH THE PDF (PROCESSES USED FOR PDF EXTRACTION)

U: UNRES. VS RES.

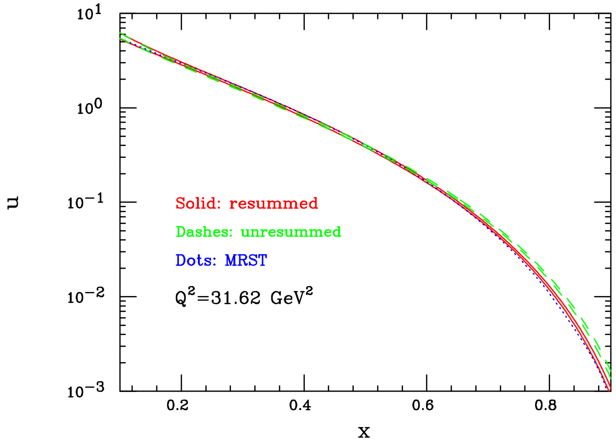


(Corcella, Magnea, 2005)

RESUMMATION

- PARTONIC CROSS SECTION RECEIVES DOUBLE LOG CORRECTIONS $\alpha_s \ln^2(1-z)$ TO ALL ORDERS IN $\alpha_s \Rightarrow$ THRESHOLD (SUDAKOV) RESUMMATION
- IN $\overline{\mathrm{MS}}$ SCHEME ONLY PARTONIC CROSS SECTION AFFECTED (NOT DGLAP EVOLUTION)
- RESUMMATION AFFECTS BOTH THE PDF (PROCESSES USED FOR PDF EXTRACTION) AND THE OBSERVABLE ITSELF

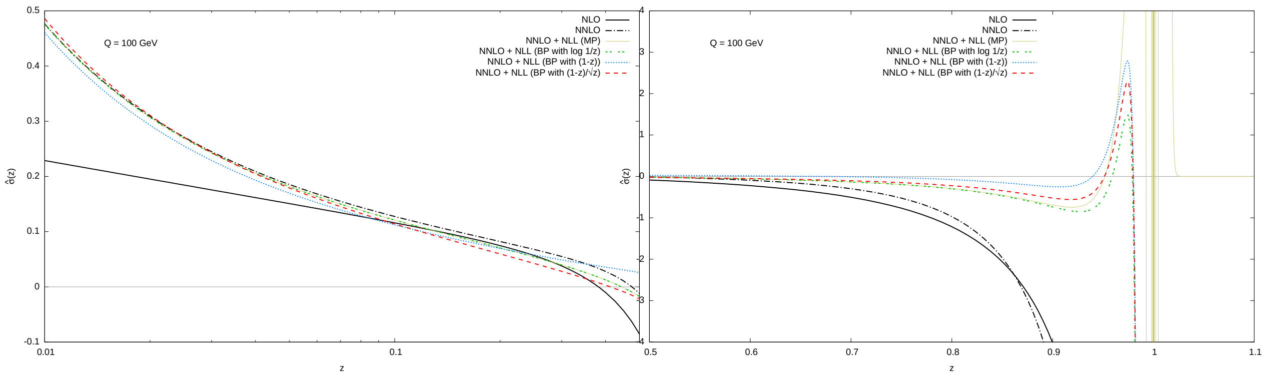
U: UNRES. VS RES.



(Corcella, Magnea, 2005)

DRELL-YAN: UNRES. VS RES.

SMALL z LARGE z



(Bonvini, SF, Ridolfi, 2009)

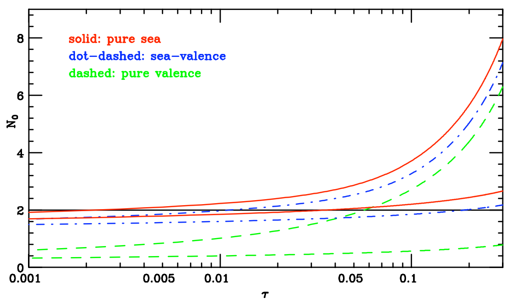
RESUMMATION: IMPACT

THE IMPACT OF RESUMMATION CAN BE ESTIMATED NOTING THAT:

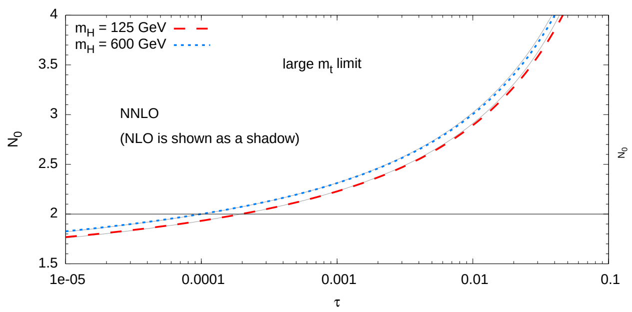
- IN MELLIN SPACE THE HADRONIC CROSS-SECTION FACTORIZES: $\sigma(N) = \hat{\sigma}(N)\mathcal{L}(N)$
- FOR GIVEN HADRONIC KINEMATICS, A SINGLE (SADDLE POINT) REAL VALUE OF $N_0 = N_0(\tau, Q^2)$ PROVIDES THE BULK OF THE CONTRIBUTION (DEP ON Q^2 VERY MILD)
- THE POSITION OF N_0 IS LARGELY DETERMINED BY THE LUMINOSITY: PROCESS INDEPENDENT, BUT DEP. ON DOMINANT PARTONIC CHANNEL
- GLUON & SEA CHANNELS HAVE SMALLER PARTONIC CM ENERGY $\Rightarrow$ LARGER N_0 FOR GIVEN τ

SADDLE N_0 VS $\tau = M_X^2/s$

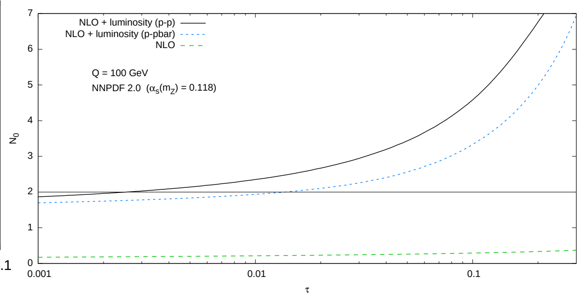
QUARK



GLUON



DRELL-YAN (NLO)



(Bonvini, SF, Ridolfi, 2009,2012)

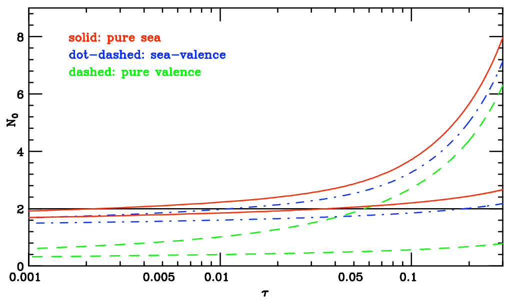
RESUMMATION: IMPACT

EXAMPLE:

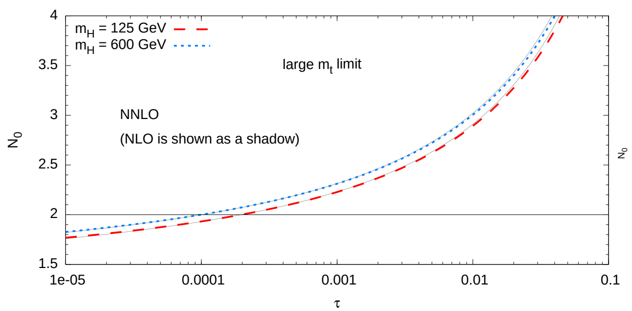
- 2 TeV W' @ LHC8 $\to \tau \sim 0.06$
- $\tau \sim 0.06 \Rightarrow N_0 \sim 4$

SADDLE N_0 VS $\tau = M_X^2/s$

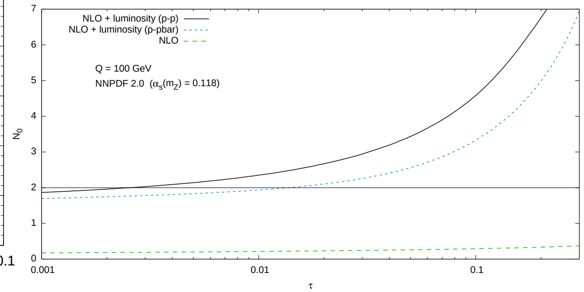
QUARK



GLUON



DRELL-YAN (NLO)



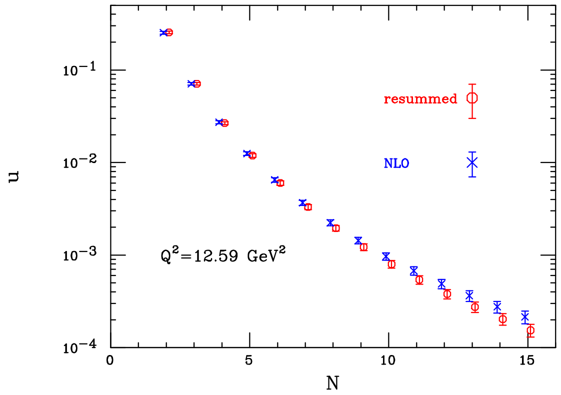
(Bonvini, SF, Ridolfi, 2009,2012)

RESUMMATION: IMPACT

EXAMPLE:

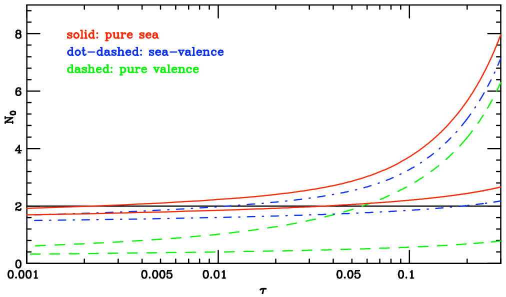
- 2 TeV W' @ LHC8 $\to \tau \sim 0.06$
- $\tau \sim 0.06 \Rightarrow N_0 \sim 4$
- RESUMMATION CORRECTION ON PDF FROM DIS AT $N \sim 4$ OF ORDER 1%

U FROM DIS: UNRES. VS RES.

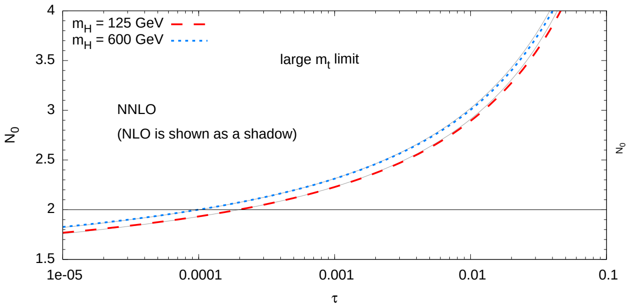


SADDLE N_0 VS $\tau = M_X^2/s$

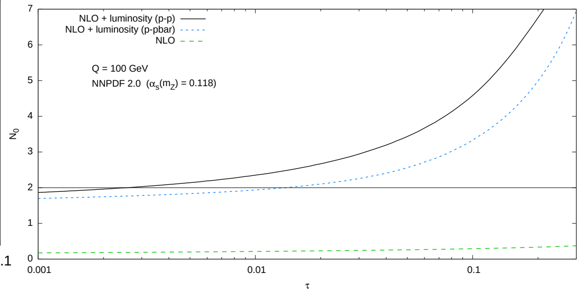
QUARK



GLUON



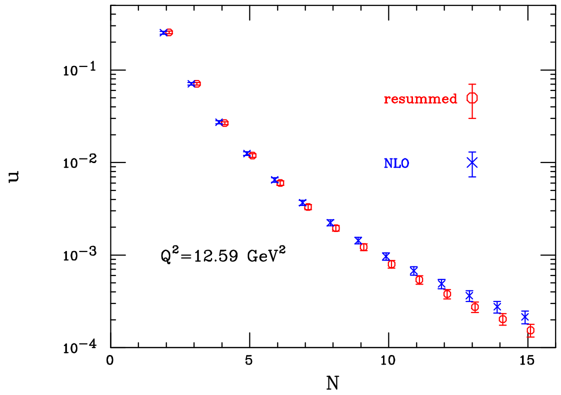
DRELL-YAN (NLO)



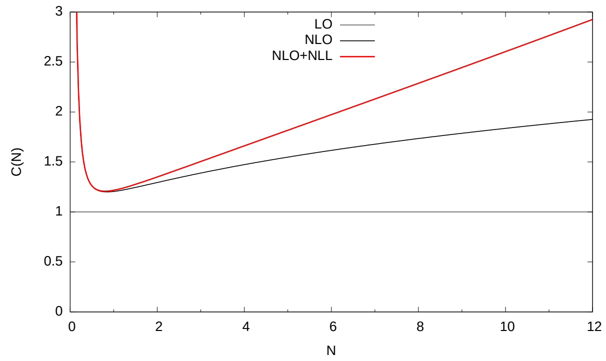
(Bonvini, SF, Ridolfi, 2009,2012)

RESUMMATION: IMPACT

U FROM DIS: UNRES. VS RES.



DRELL-YAN: UNRES. VS RES.

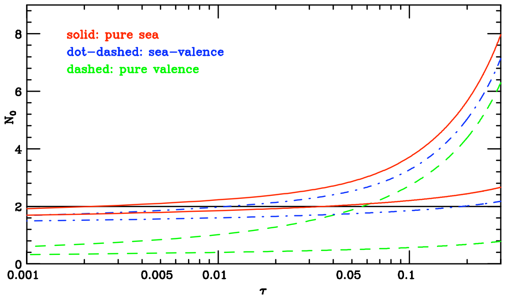


EXAMPLE:

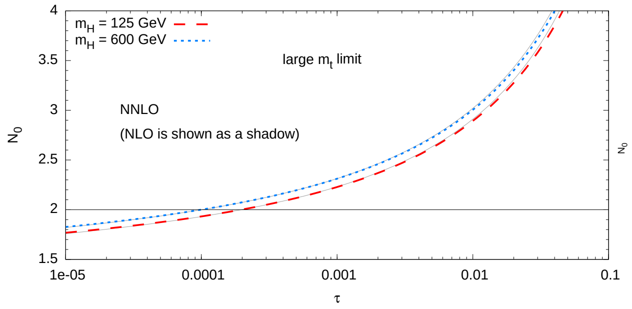
- 2 TeV W' @ LHC8 $\rightarrow \tau \sim 0.06$
- $\tau \sim 0.06 \Rightarrow N_0 \sim 4$
- RESUMMATION CORRECTION ON PDF FROM DIS AT $N \sim 4$ OF ORDER 1%
- RESUMMATION CORRECTION ON PROCESS (DY) AT $N \sim 4$ OF ORDER 5%

SADDLE N_0 VS $\tau = M_X^2/s$

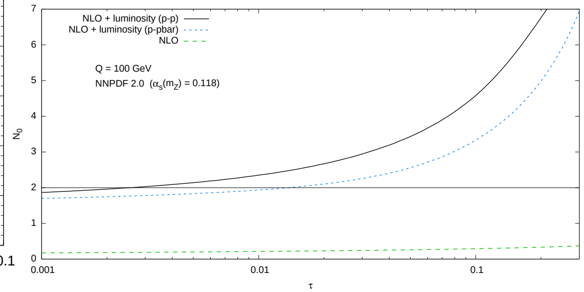
QUARK



GLUON



DRELL-YAN (NLO)



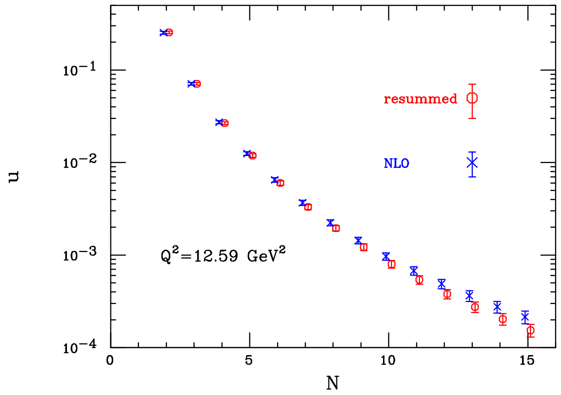
(Bonvini, SF, Ridolfi, 2009,2012)

RESUMMATION: IMPACT

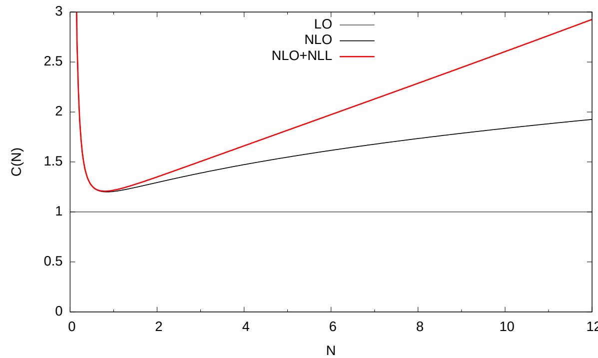
EXAMPLE:

- 2 TeV W' @ LHC8 $\to \tau \sim 0.06$
- $\tau \sim 0.06 \Rightarrow N_0 \sim 4$
- RESUMMATION CORRECTION ON PDF FROM DIS AT $N \sim 4$ OF ORDER 1%
- RESUMMATION CORRECTION ON PROCESS (DY) AT $N \sim 4$ OF ORDER 5%
- IMPACT OF SUDAKOV MODERATE, RELEVANT FOR PRECISION PHYSICS

U FROM DIS: UNRES. VS RES.

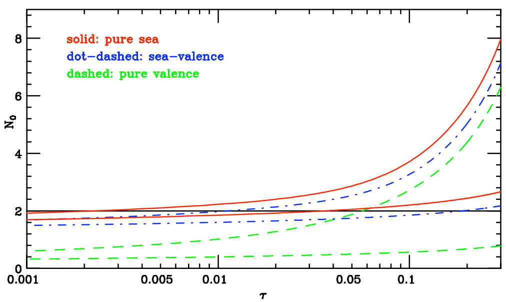


DRELL-YAN: UNRES. VS RES.

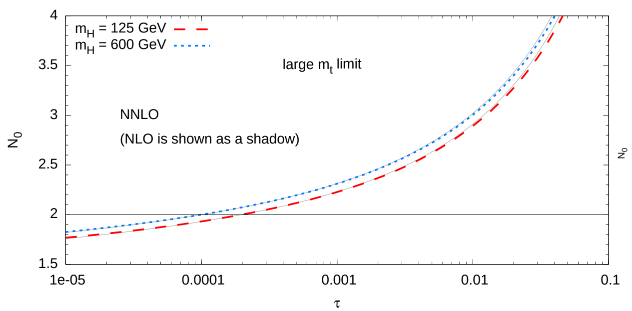


SADDLE N_0 VS $\tau = M_X^2/s$

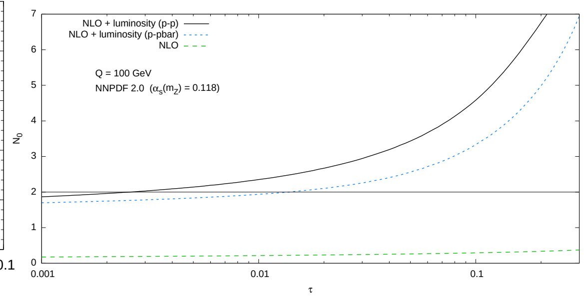
QUARK



GLUON



DRELL-YAN (NLO)



(Bonvini, SF, Ridolfi, 2009,2012)

CONCLUSION

- UNCERTAINTIES ON VALENCE PDFs IN EXTRAPOLATION $x \gtrsim 0.5$ REGION MUST BE ESTIMATED MORE ACCURATELY, PERHAPS UNDERESTIMATED
- NUCLEAR CORRECTIONS MAY HAVE AN IMPACT AT ONE-SIGMA LEVEL IN THAT REGION
- SUDAKOV CORRECTIONS MOSTLY RELEVANT FOR PRECISION PHYSICS (PERCENT LEVEL)

CONCLUSION

- UNCERTAINTIES ON VALENCE PDFS IN EXTRAPOLATION $x \gtrsim 0.5$ REGION MUST BE ESTIMATED MORE ACCURATELY, PERHAPS UNDERESTIMATED
- NUCLEAR CORRECTIONS MAY HAVE AN IMPACT AT ONE-SIGMA LEVEL IN THAT REGION
- SUDAKOV CORRECTIONS MOSTLY RELEVANT FOR PRECISION PHYSICS (PERCENT LEVEL)
- IMPROVEMENT REQUIRES NEW LHC DATA:
  - HIGH-MASS DRELL-YAN
  - HIGH-p_T JETS
  - $\ldots$